US010641994B2

(12) United States Patent
Fang et al.

(10) Patent No.: US 10,641,994 B2
(45) Date of Patent: May 5, 2020

(54) **CAMERA OPTICAL LENS**

(71) Applicant: **AAC Technologies Pte. Ltd.**, Singapore (SG)

(72) Inventors: **Chunhuan Fang**, Shenzhen (CN); **Lei Zhang**, Shenzhen (CN); **Yanmei Wang**, Shenzhen (CN); **Yang Zhang**, Shenzhen (CN)

(73) Assignee: **AAC Technologies Pte. Ltd.**, Singapore (SG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 71 days.

(21) Appl. No.: **15/976,320**

(22) Filed: **May 10, 2018**

(65) **Prior Publication Data**

US 2019/0227271 A1 Jul. 25, 2019

(30) **Foreign Application Priority Data**

Jan. 23, 2018 (CN) 2018 1 0065453
Jan. 23, 2018 (CN) 2018 1 0065454

(51) **Int. Cl.**

G02B 13/18	(2006.01)
G02B 9/62	(2006.01)
G02B 13/00	(2006.01)

(52) **U.S. Cl.**
CPC ***G02B 13/0045*** (2013.01); ***G02B 9/62*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 13/04; G02B 13/0045; G02B 9/62
USPC 359/713, 752, 756, 757
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,796,529 A * 8/1998 Park G02B 9/62 359/756

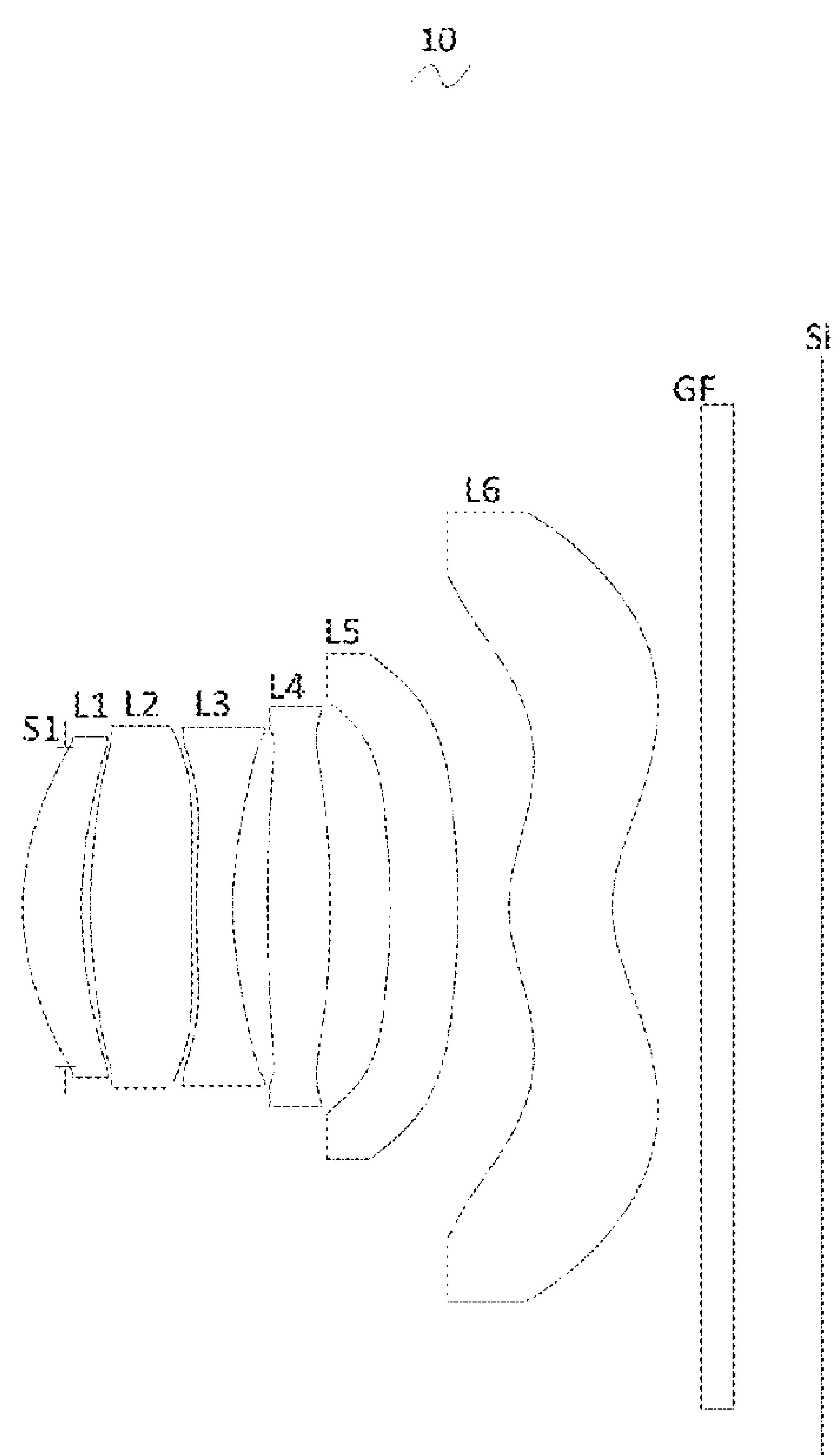
* cited by examiner

Primary Examiner — William Choi
(74) *Attorney, Agent, or Firm* — IPro, PLLC; Na Xu

(57) **ABSTRACT**

The present disclosure discloses a camera optical lens. The camera optical lens including, in an order from an object side to an image side, a first lens, a second lens having a positive refractive power, a third lens having a negative refractive power, a fourth lens, a fifth lens, and a sixth lens. The first lens is made of plastic material, the second lens is made of glass material, the third lens is made of plastic material, the fourth lens is made of plastic material, the fifth lens is made of plastic material, and the sixth lens is made of plastic material. The camera optical lens further satisfies specific conditions.

21 Claims, 9 Drawing Sheets



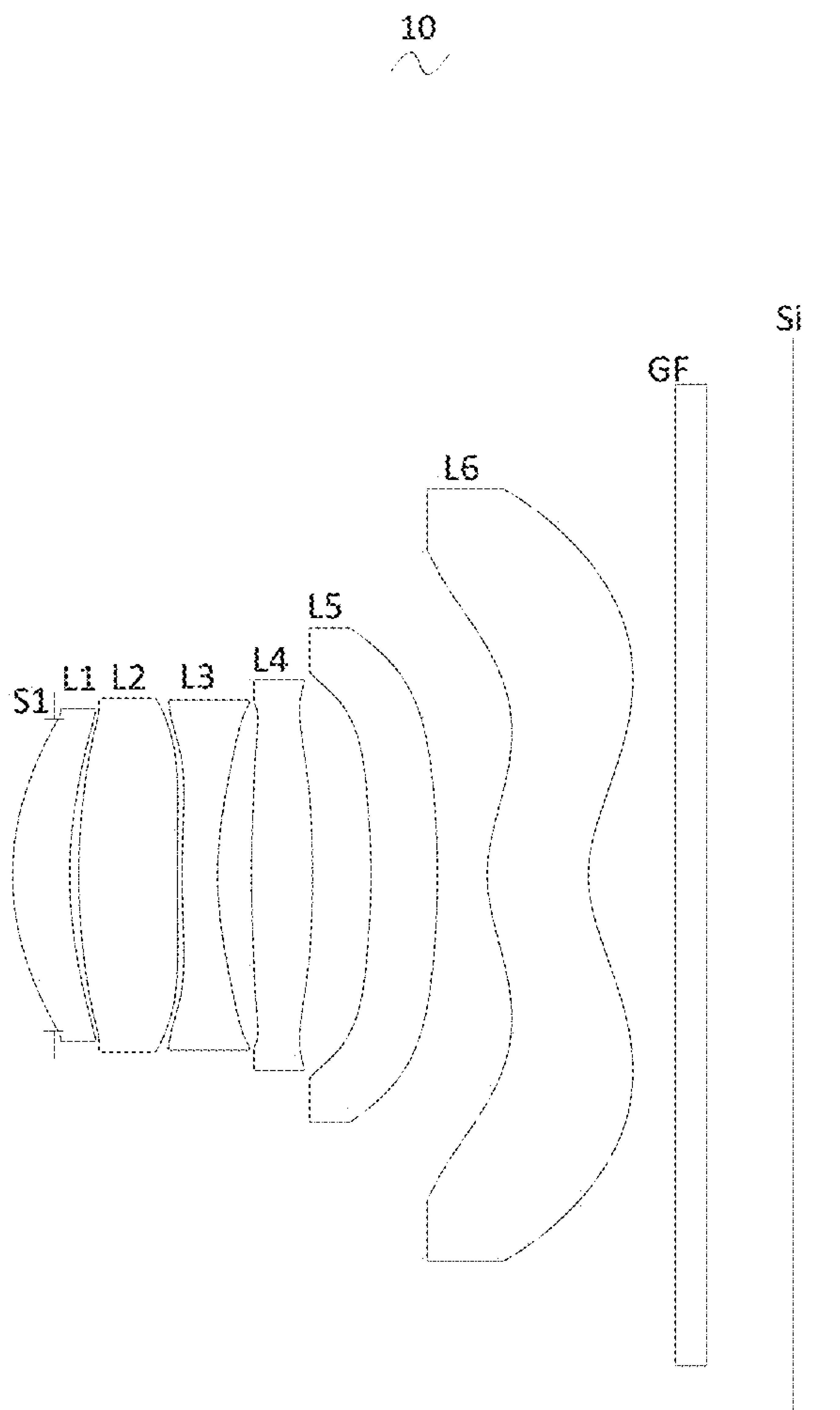


Fig. 1

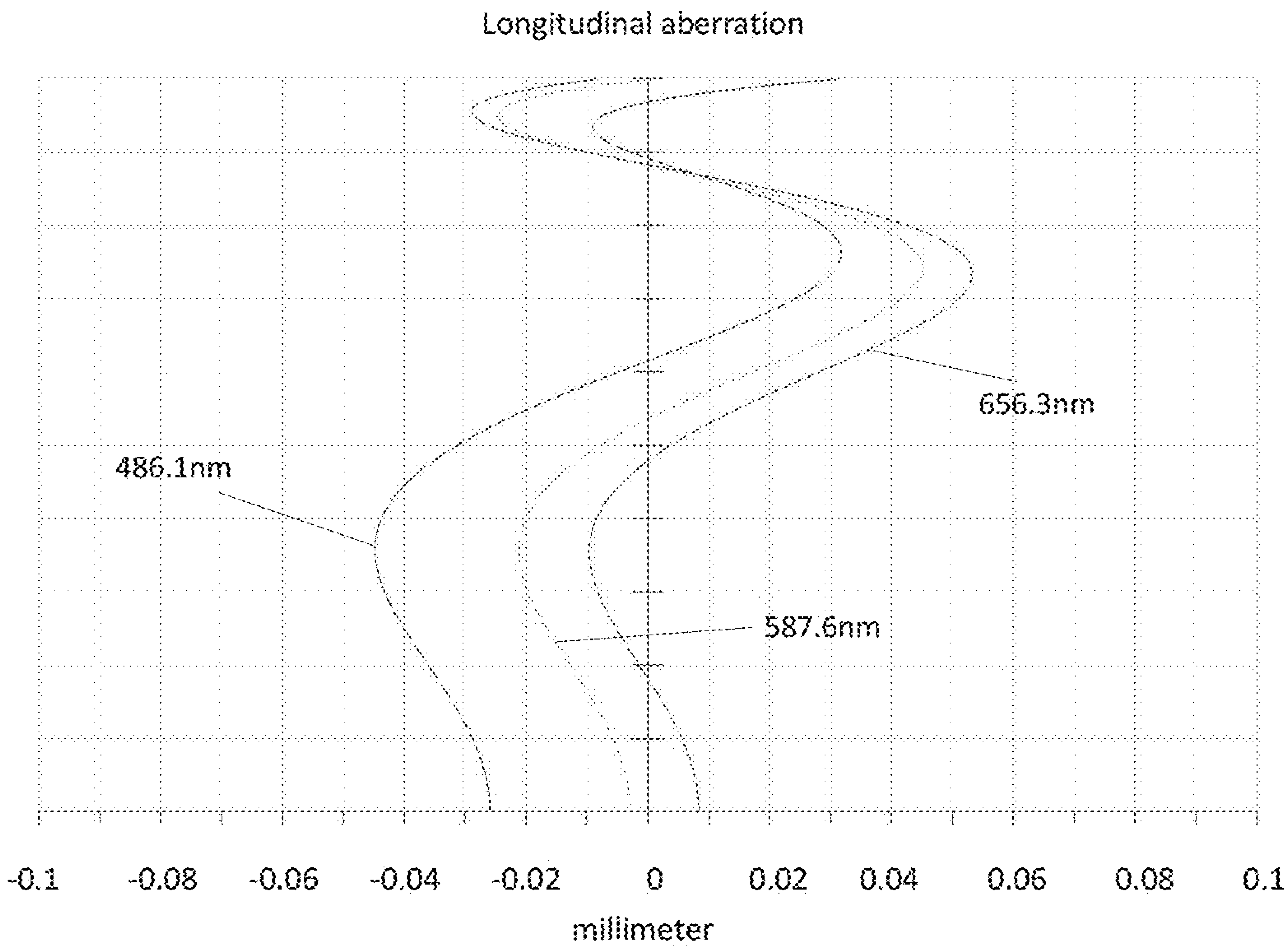

Longitudinal aberration
656.3nm
486.1nm
587.6nm
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
millimeter

Fig.2

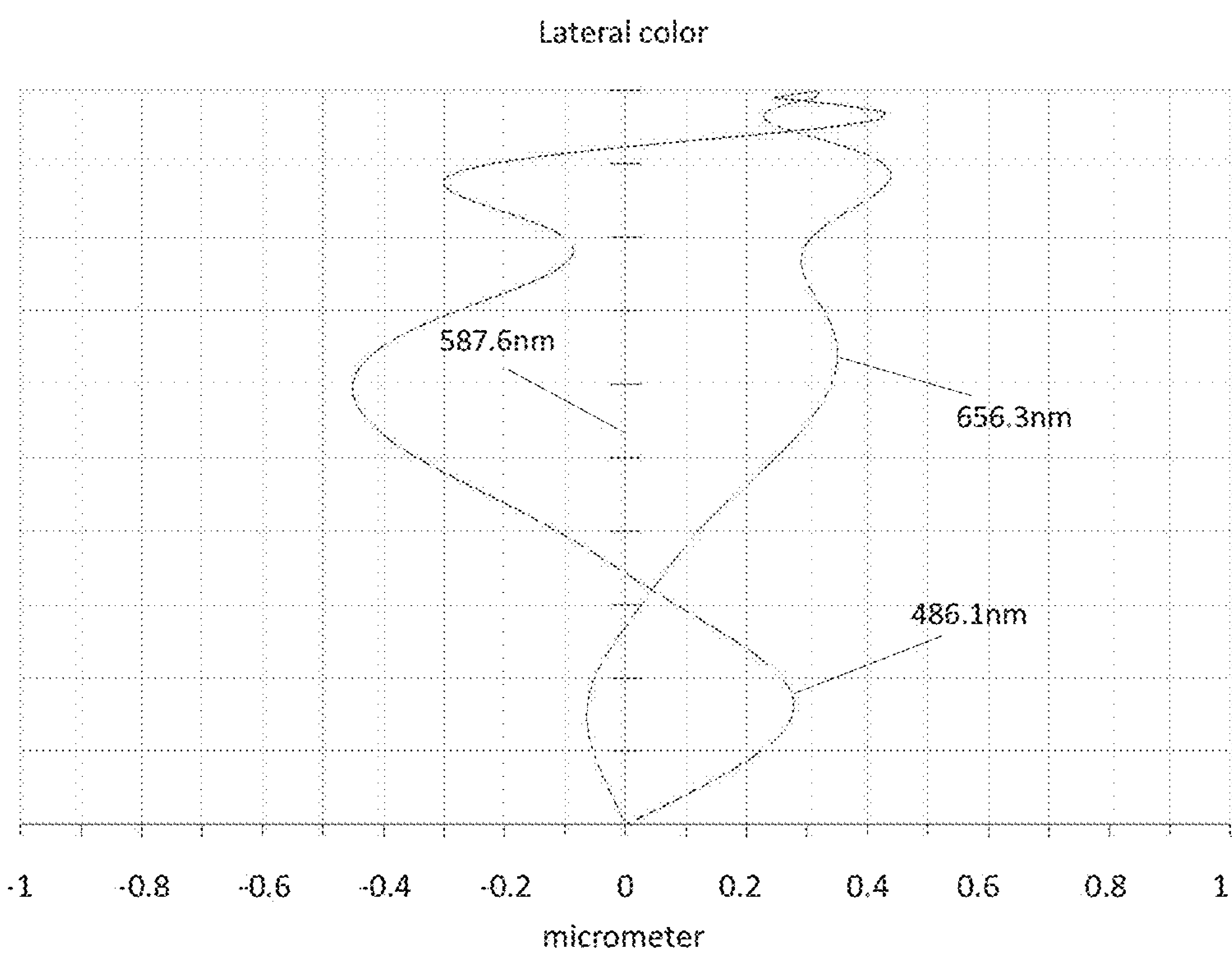

Lateral color
587.6nm
656.3nm
486.1nm
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
micrometer

Fig.3

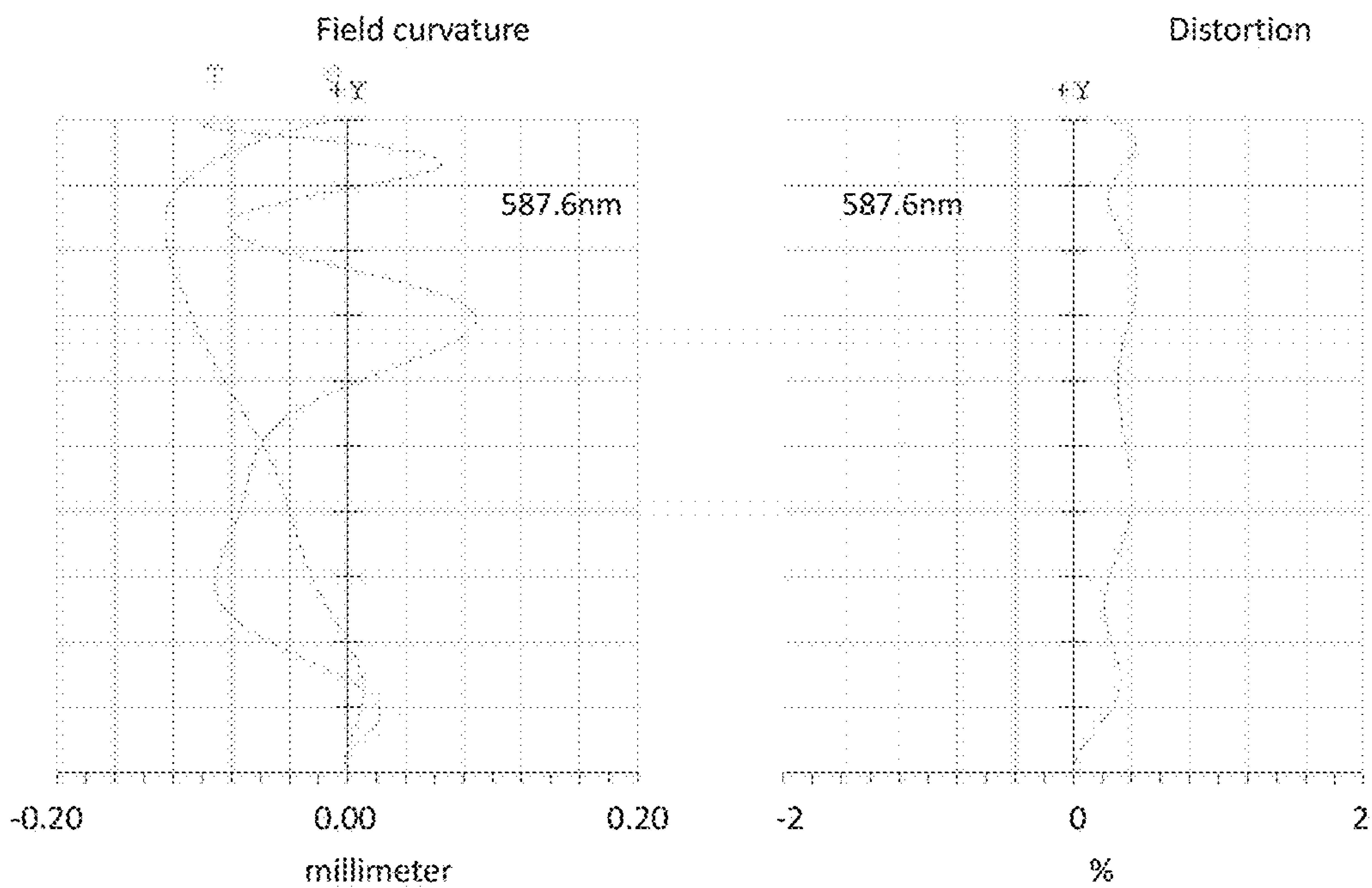

Field curvature
T
S
+Y
587.6nm
-0.20
0.00
0.20
millimeter
Distortion
+Y
587.6nm
-2
0
2
%

Fig.4

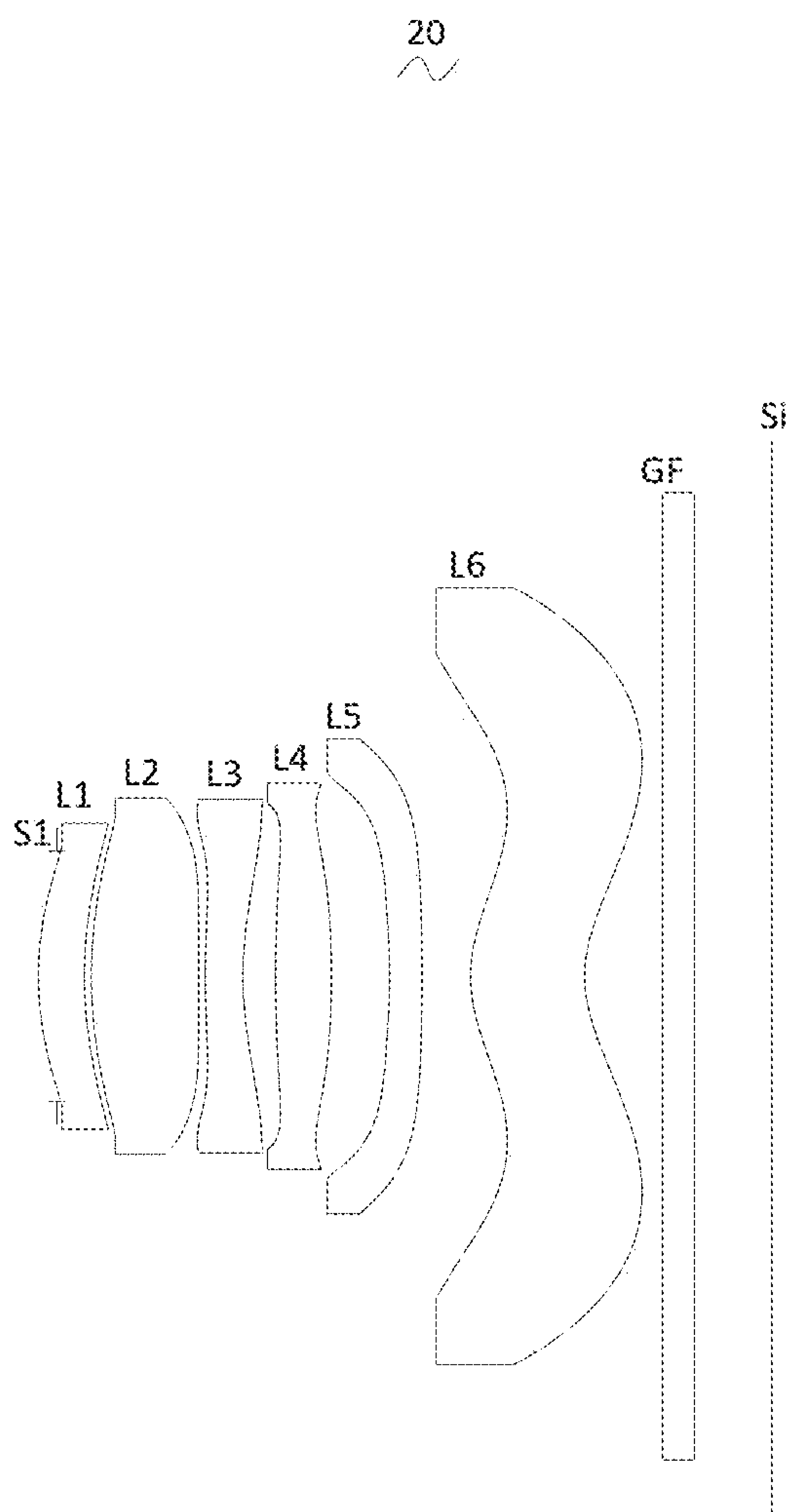


Fig.5

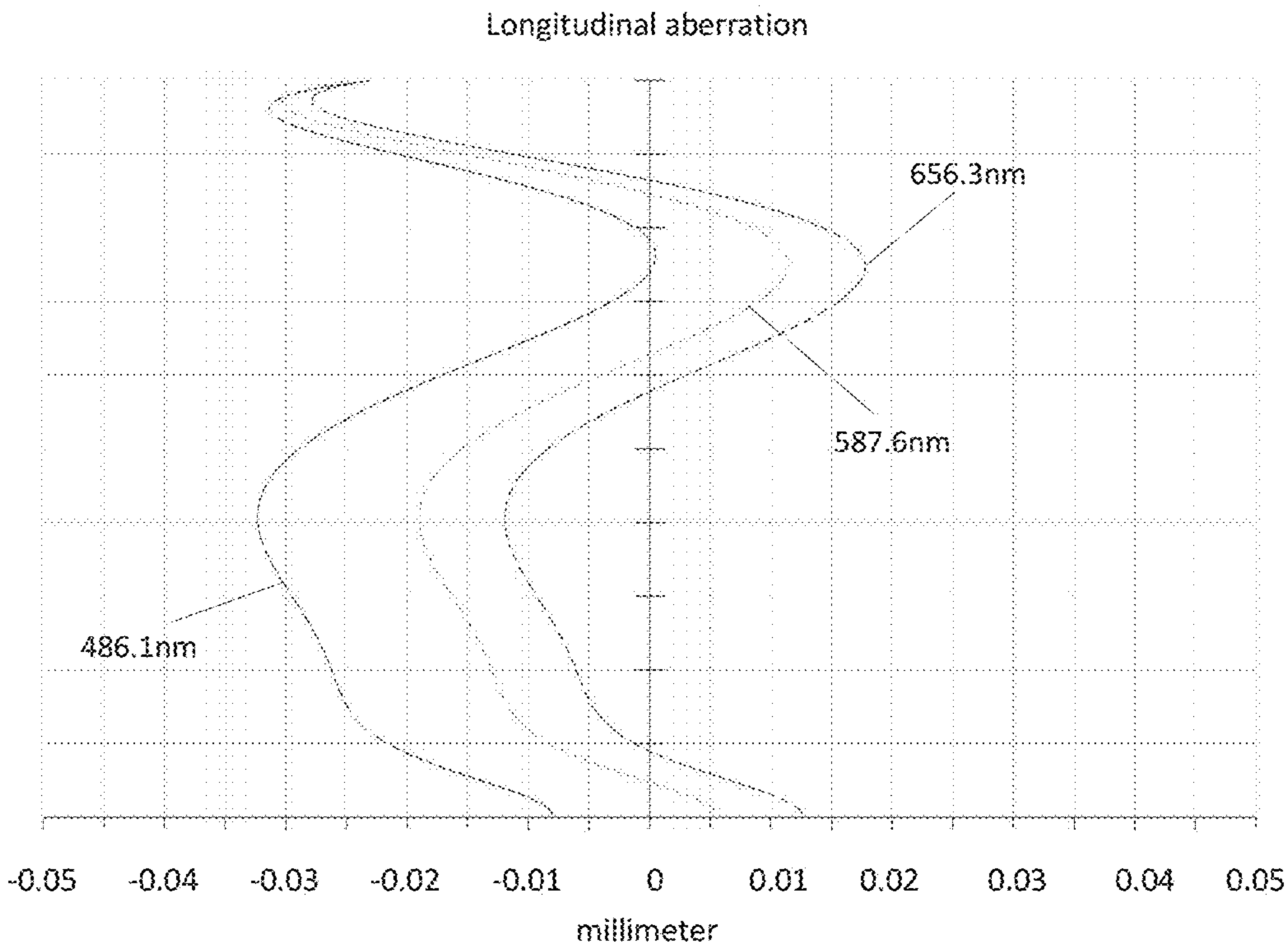

Longitudinal aberration
656.3nm
587.6nm
486.1nm
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
millimeter

Fig.6

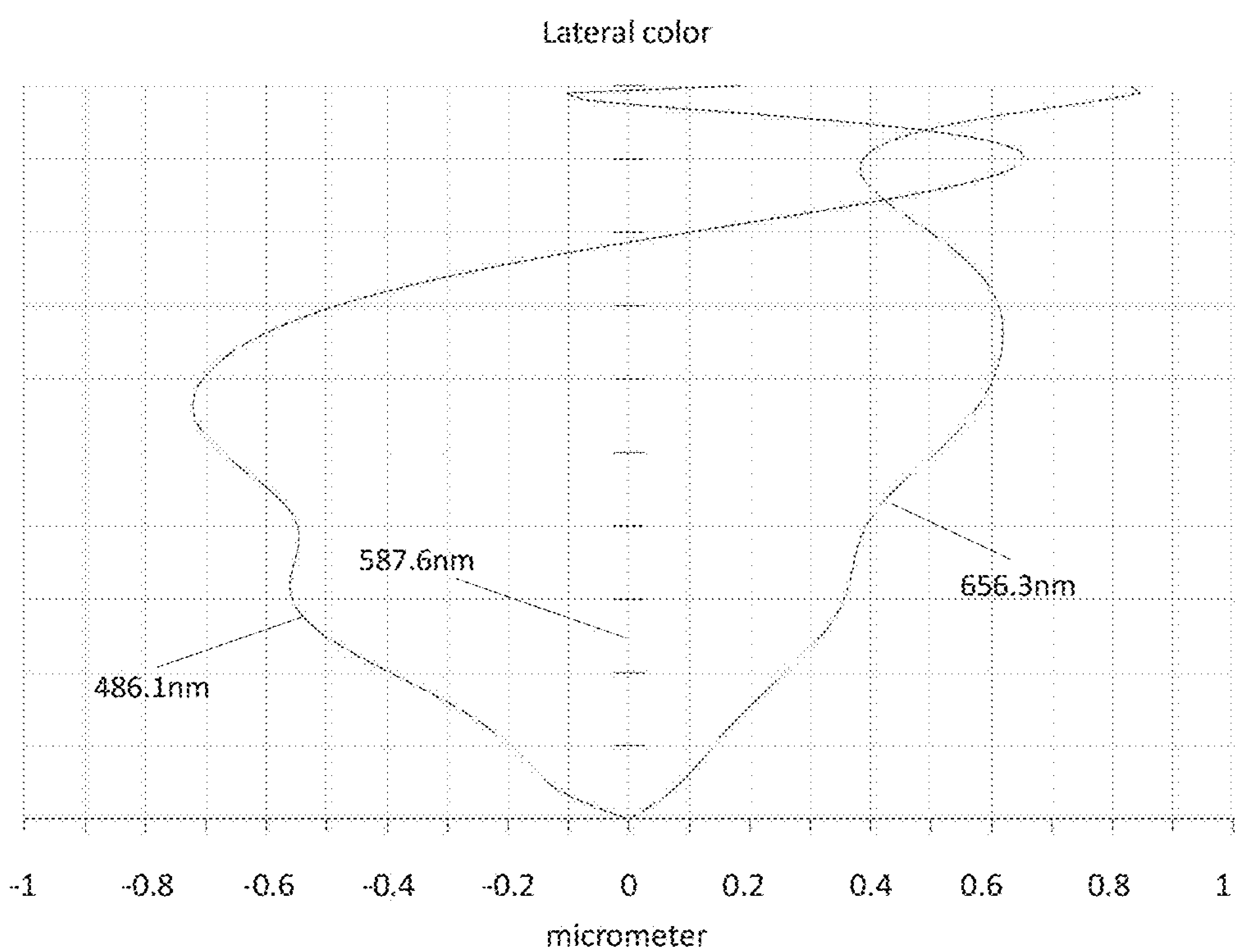

Lateral color
587.6nm
656.3nm
486.1nm
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
micrometer

Fig.7

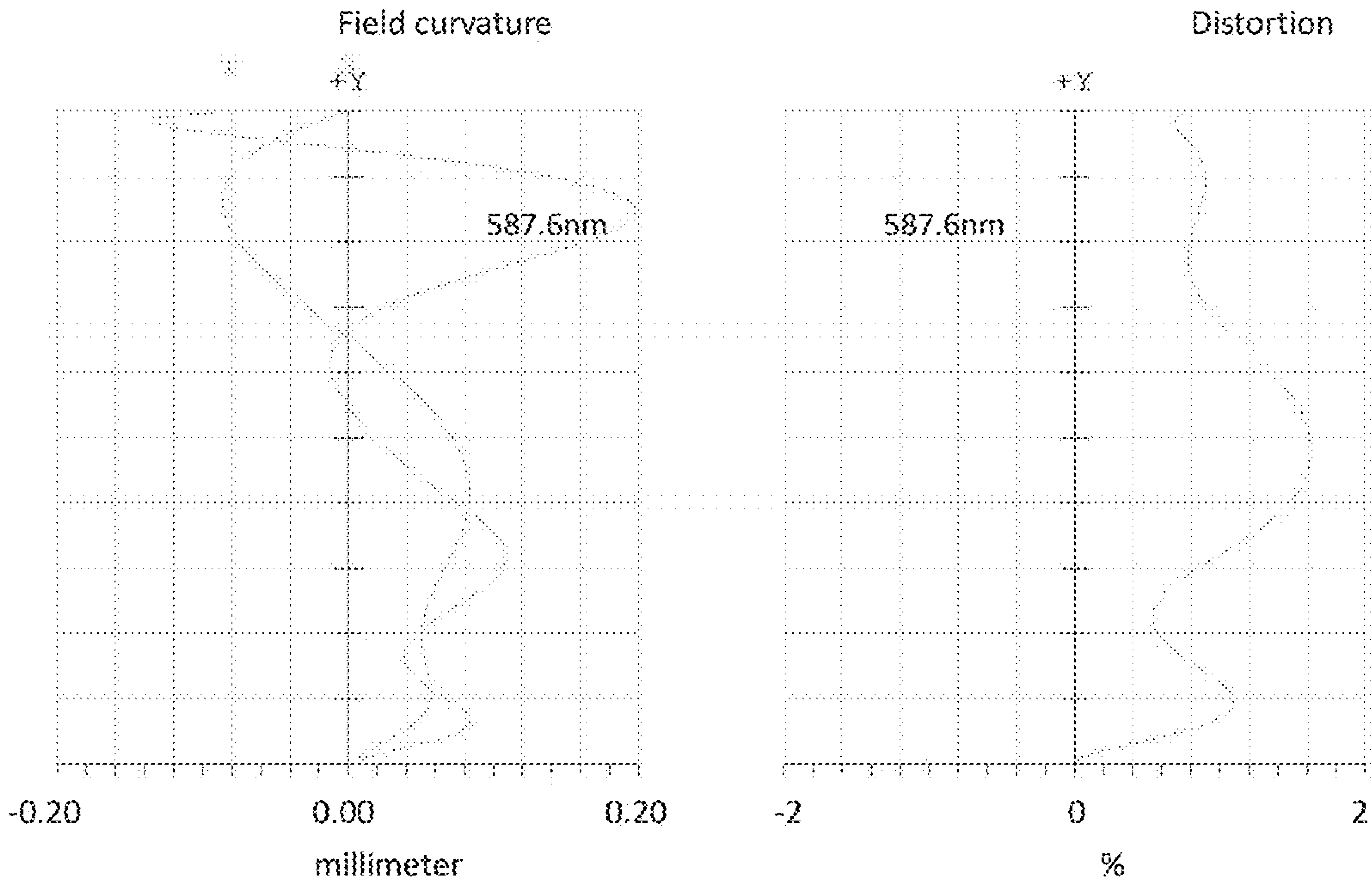

Field curvature
+Y
587.6nm
-0.20
0.00
0.20
millimeter
Distortion
+Y
587.6nm
-2
0
2
%

Fig.8

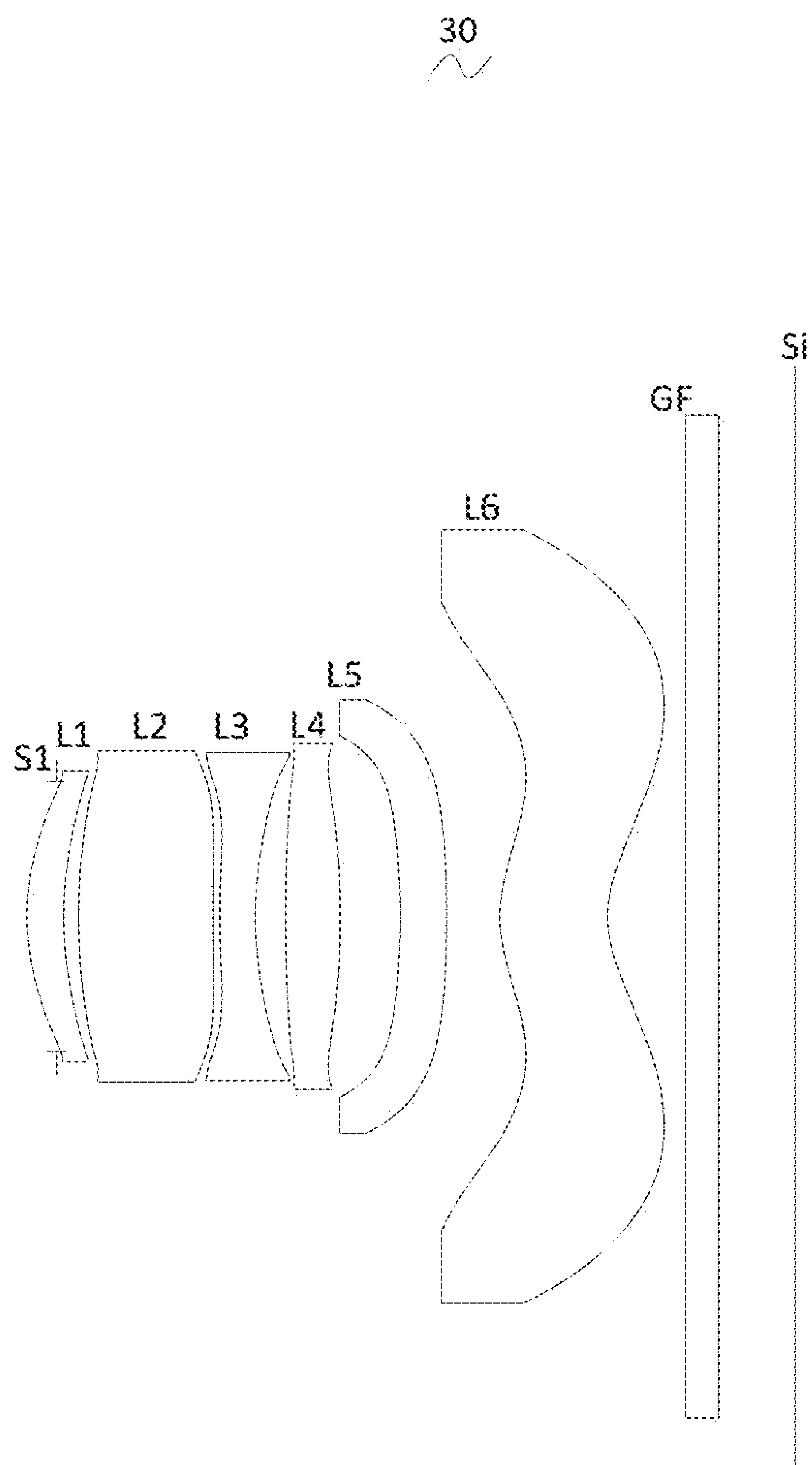


Fig.9

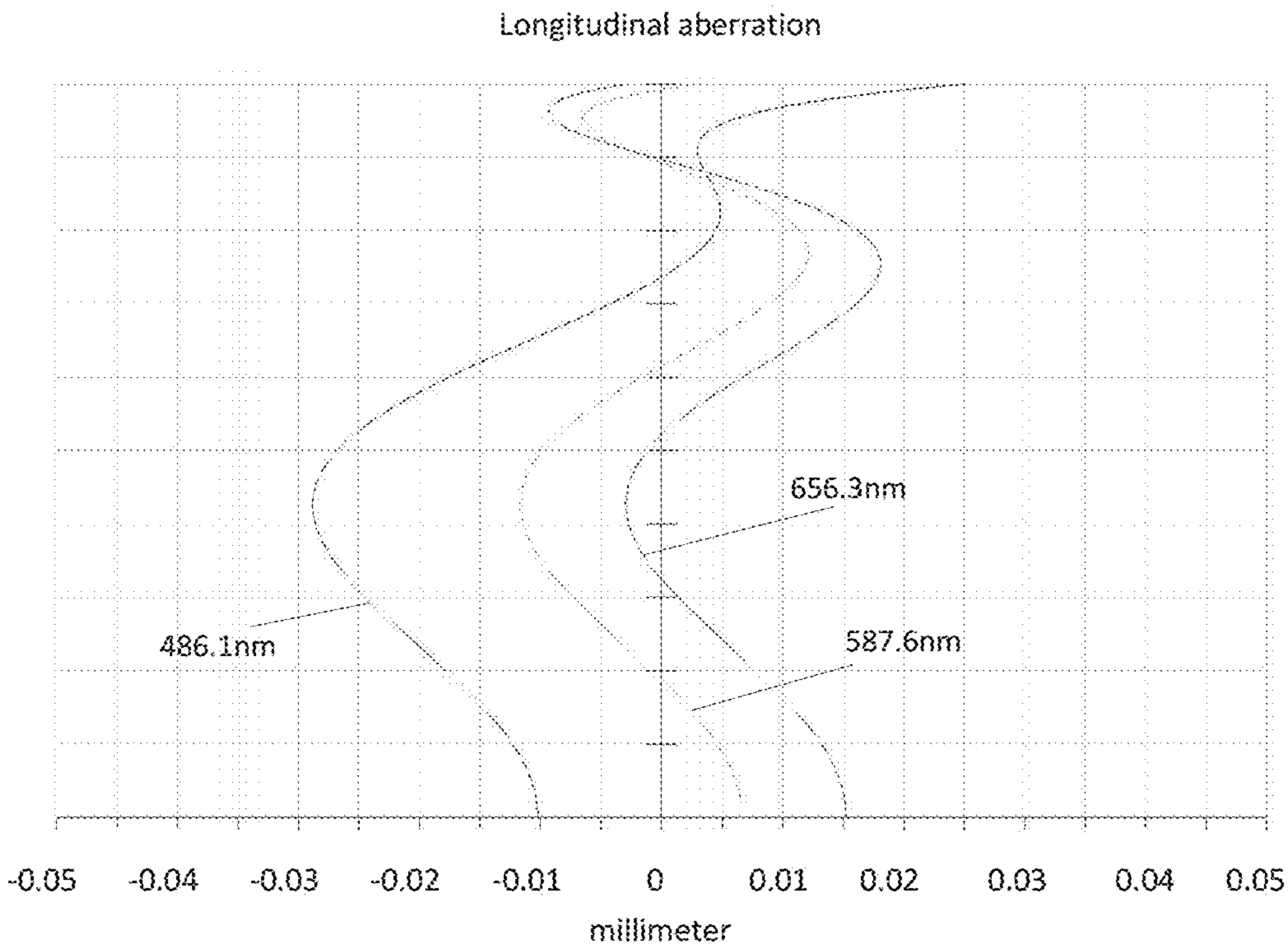

Longitudinal aberration
656.3nm
486.1nm
587.6nm
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
millimeter

Fig.10

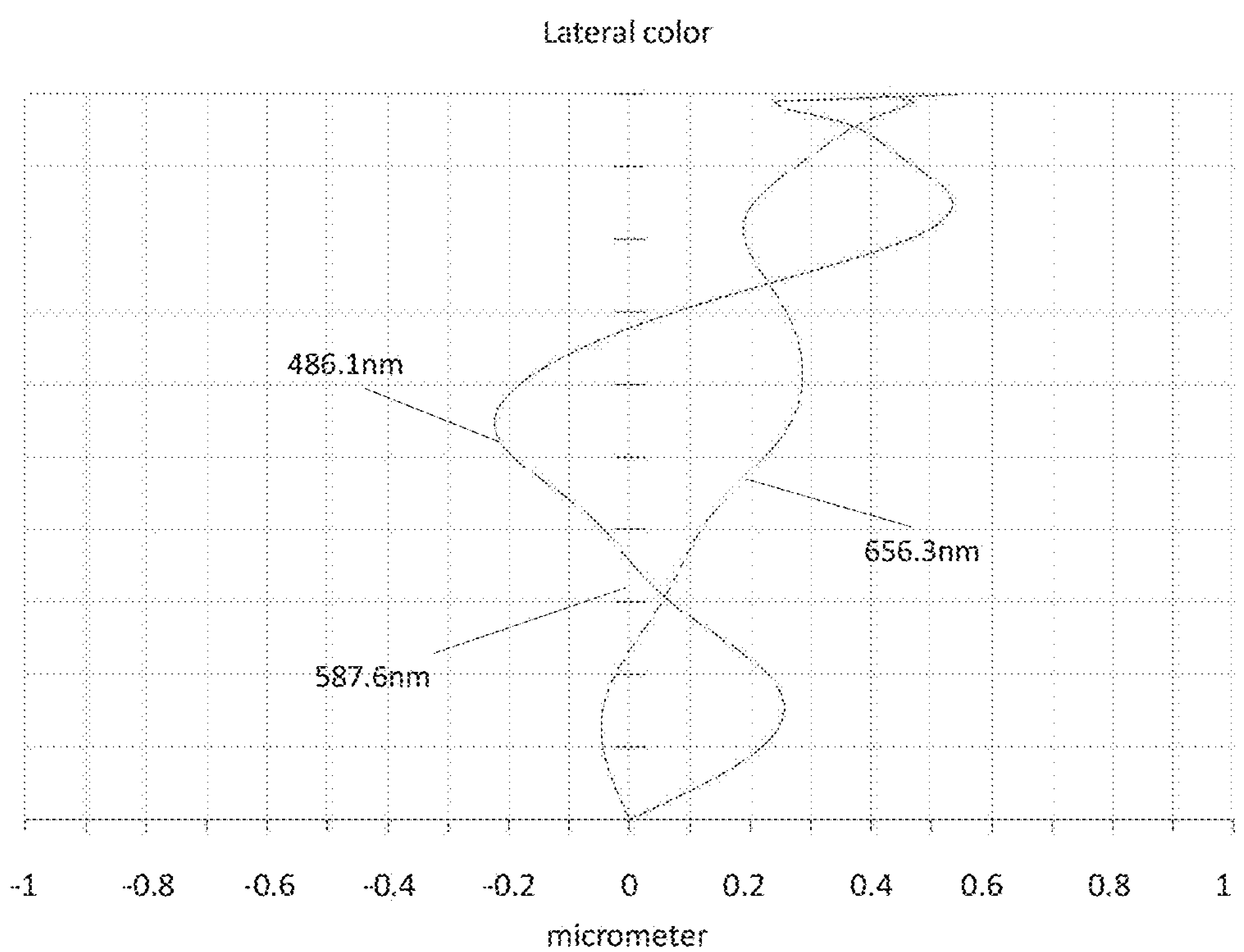
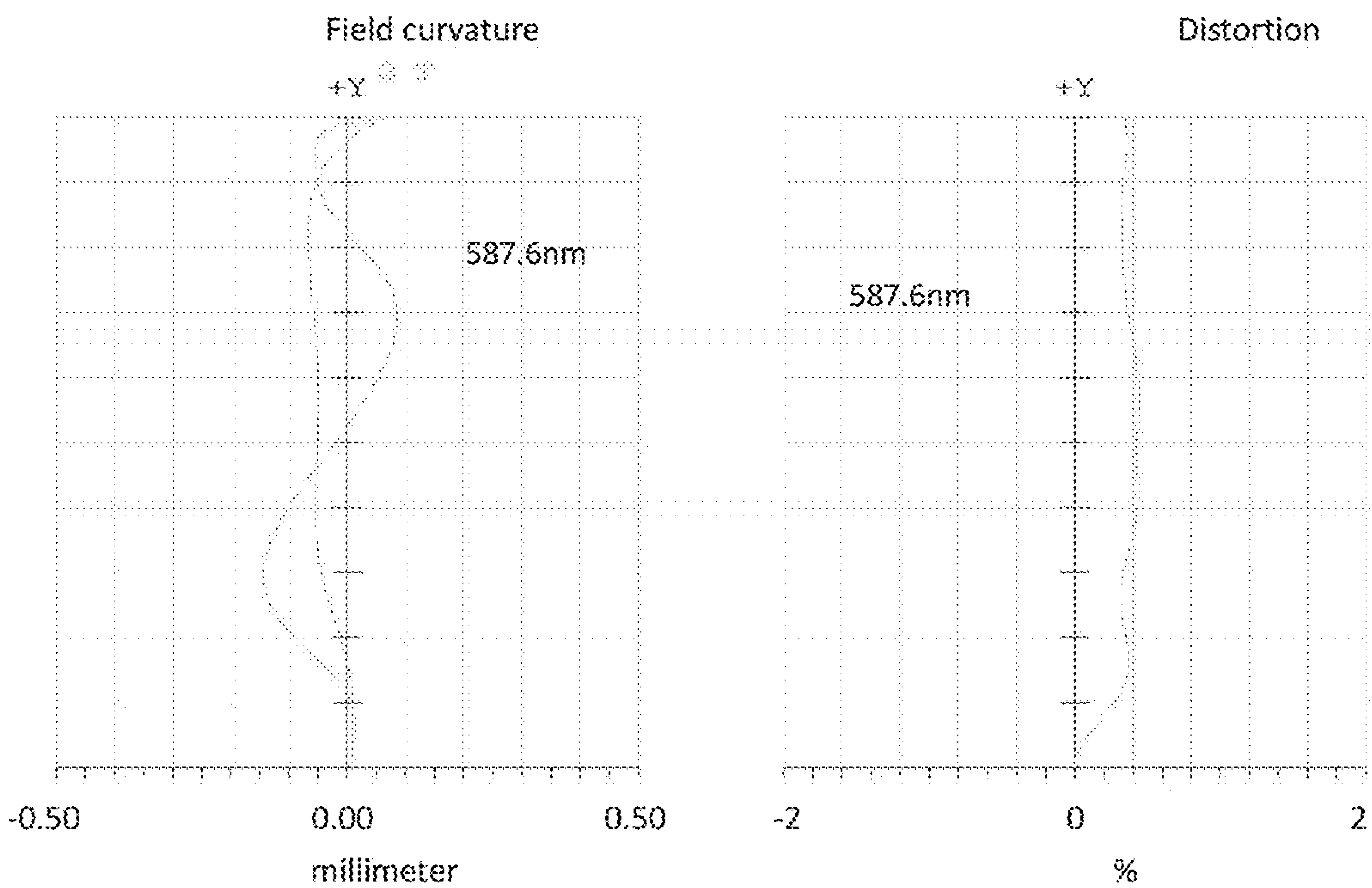

Lateral color
486.1nm
656.3nm
587.6nm
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
micrometer

Fig.11



Field curvature
+Y
587.6nm
-0.50
0.00
0.50
millimeter
Distortion
+Y
587.6nm
-2
0
2
%

Fig.12

CAMERA OPTICAL LENS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit of Chinese Patent Applications Ser. No. 201810065454.5 and Ser. No. 201810065453.0 filed on Jan. 23, 2018, the entire content of which is incorporated herein by reference.

FIELD OF THE PRESENT DISCLOSURE

The present disclosure relates to optical lens, in particular to a camera optical lens suitable for handheld devices such as smart phones and digital cameras and imaging devices.

DESCRIPTION OF RELATED ART

With the emergence of smart phones in recent years, the demand for miniature camera lens is increasing day by day, but the photosensitive devices of general camera lens are no other than Charge Coupled Device (CCD) or Complementary metal-Oxide Semiconductor Sensor (CMOS sensor), and as the progress of the semiconductor manufacturing technology makes the pixel size of the photosensitive devices shrink, coupled with the current development trend of electronic products being that their functions should be better and their shape should be thin and small, miniature camera lens with good imaging quality therefor has become a mainstream in the market. In order to obtain better imaging quality, the lens that is traditionally equipped in mobile phone cameras adopts a three-piece or four-piece lens structure. And, with the development of technology and the increase of the diverse demands of users, and under this circumstances that the pixel area of photosensitive devices is shrinking steadily and the requirement of the system for the imaging quality is improving constantly, the five-piece, six-piece and seven-piece lens structure gradually appear in lens design. There is an urgent need for ultra-thin wide-angle camera lenses which have good optical characteristics and the chromatic aberration of which is fully corrected.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the exemplary embodiments can be better understood with reference to the following drawings. The components in the drawing are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the present disclosure.

FIG. **1** is a schematic diagram of a camera optical lens in accordance with a first embodiment of the present invention;

FIG. **2** shows the longitudinal aberration of the camera optical lens shown in FIG. **1**;

FIG. **3** shows the lateral color of the camera optical lens shown in FIG. **1**;

FIG. **4** shows a schematic diagram of the field curvature and distortion of the camera optical lens shown in FIG. **1**;

FIG. **5** is a schematic diagram of a camera optical lens in accordance with a second embodiment of the present invention;

FIG. **6** shows the longitudinal aberration of the camera optical lens shown in FIG. **5**;

FIG. **7** shows the lateral color of the camera optical lens shown in FIG. **5**;

FIG. **8** shows a schematic diagram of the field curvature and distortion of the camera optical lens shown in FIG. **5**:

FIG. **9** is a schematic diagram of a camera optical lens in accordance with a third embodiment of the present invention;

FIG. **10** shows the longitudinal aberration of the camera optical lens shown in FIG. **9**;

FIG. **11** shows the lateral color of the camera optical lens shown in FIG. **9**;

FIG. **12** shows a schematic diagram of the field curvature and distortion of the camera optical lens shown in FIG. **9**.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

The present disclosure will hereinafter be described in detail with reference to several exemplary embodiments. To make the technical problems to be solved, technical solutions and beneficial effects of the present disclosure more apparent, the present disclosure is described in further detail together with the figure and the embodiments. It should be understood the specific embodiments described hereby is only to explain the disclosure, not intended to limit the disclosure.

Embodiment 1

As referring to FIG. **1**, the present invention provides a camera optical lens **10**. FIG. **1** shows the camera optical lens **10** of embodiment 1 of the present invention, the camera optical lens **10** comprises 6 lenses. Specifically, from the object side to the image side, the camera optical lens **10** comprises in sequence: an aperture S**1**, a first lens L**1**, a second lens L**2**, a third lens L**3**, a fourth lens L**4**, a fifth lens L**5**, and a sixth lens L**6**. Optical element like optical filter GF can be arranged between the sixth lens L**6** and the image surface Si.

The first lens L**1** is made of plastic material, the second lens L**2** is made of glass material, the third lens L**3** is made of plastic material, the fourth lens L**4** is made of plastic material, the fifth lens L**5** is made of plastic material, and the sixth lens L**6** is made of plastic material.

Here, the focal length of the whole camera optical lens **10** is defined as f, the focal length of the first lens is defined as f1. The camera optical lens **10** further satisfies the following condition: $0.1 \leq f1/f \leq 10$, which fixes the positive refractive power of the first lens L**1**. If the lower limit of the set value is exceeded, although it benefits the ultra-thin development of lenses, but the positive refractive power of the first lens L**1** will be too strong, problem like aberration is difficult to be corrected, and it is also unfavorable for wide-angle development of lens. On the contrary, if the upper limit of the set value is exceeded, the positive refractive power of the first lens L**1** becomes too weak, it is then difficult to develop ultra-thin lenses. Preferably, the following condition shall be satisfied, $0.88 \leq f1/f \leq 9.71$.

The refractive power of the second lens L**2** is defined as n2. Here the following condition should be satisfied: $1.7 \leq n2 \leq 2.2$. This condition fixes the refractive power of the second lens L**2**, and when the value of the refractive power within this range benefits the ultra-thin development of lenses, and it also benefits the correction of aberration. Preferably, the following condition shall be satisfied, $1.7 \leq n2 \leq 2.1$.

The thickness on-axis of the second lens L**2** is defined as d3, and the total optical length of the camera optical lens **10** is defined as TTL. The following condition: $0.01 \leq d3/TTL \leq 0.2$ should be satisfied. This condition fixes the ratio between the thickness on-axis of the second lens L**2** and the total optical length TTL. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.075 \le d3/TTL \le 0.19$ shall be satisfied.

When the focal length of the camera optical lens **10** of the present invention, the focal length of each lens, the refractive power of the related lens, and the total optical length, the thickness on-axis and the curvature radius of the camera optical lens satisfy the above conditions, the camera optical lens **10** has the advantage of high performance and satisfies the design requirement of low TTL.

In this embodiment, the first lens L**1** has a positive refractive power with a convex object side surface relative to the proximal axis and a concave image side surface relative to the proximal axis.

The curvature radius of the object side surface of the first lens L**1** is defined as R1, the curvature radius of the image side surface of the first lens L**1** is defined as R2. The camera optical lens **10** further satisfies the following condition: $-17.80 \le (R1+R2)/(R1-R2) \le -2.72$, which fixes the shape of the first lens L**1**, by which, the shape of the first lens L**1** can be reasonably controlled and it is effectively for correcting spherical aberration of the camera optical lens. Preferably, the condition $-11.12 \le (R1+R2)/(R1-R2) \le -3.39$ shall be satisfied.

The thickness on-axis of the first lens L is defined as d1. The following condition: $0.12 \le d1 \le 0.57$ should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.19 \le d1 \le 0.46$ shall be satisfied.

In this embodiment, the second lens L**2** has a positive refractive power with a convex object side surface and a concave image side surface relative to the proximal axis.

The focal length of the whole camera optical lens **10** is f, the focal length of the second lens L**2** is f2. The following condition should be satisfied: $0.73 \le f2/f \le 2.86$. When the condition is satisfied, the positive refractive power of the second lens L**2** is controlled within reasonable scope, the spherical aberration caused by the first lens L**1** which has positive refractive power and the field curvature of the system then can be reasonably and effectively balanced. Preferably, the condition $1.17 \le f2/f \le 2.29$ should be satisfied.

The curvature radius of the object side surface of the second lens L**2** is defined as R3, the curvature radius of the image side surface of the second lens L**2** is defined as R4. The following condition should be satisfied: $-2.55 \le (R3+R4)/(R3-R4) \le -0.73$, which fixes the shape of the second lens L**2**, when the value is beyond this range, with the development into the direction of ultra-thin and wide-angle lenses, problem like aberration of the on-axis Chromatic aberration is difficult to be corrected. Preferably, the following condition shall be satisfied, $-1.60 \le (R3+R4)/(R3-R4) \le -0.92$.

The thickness on-axis of the second lens L**2** is defined as d3. The following condition: $0.33 \le d3 \le 1.29$ should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.53 \le d3 \le 1.03$ shall be satisfied.

In this embodiment, the third lens L**3** has negative refractive power with a convex object side surface and a concave image side surface relative to the proximal axis.

The focal length of the whole camera optical lens **10** is f, the focal length of the third lens L**3** is f3. The following condition should be satisfied: $-5.31 \le f3/f \le -1.09$, by which the field curvature of the system then can be reasonably and effectively balanced. Preferably, the condition $-3.32 \le f3/f \le -1.37$ should be satisfied.

The curvature radius of the object side surface of the third lens L**3** is defined as R5, the curvature radius of the image side surface of the third lens L**3** is defined as R6. The following condition should be satisfied: $1.22 \le (R5+R6)/(R5-R6) \le 4.26$, which is beneficial for the shaping of the third lens L**3**, and bad shaping and stress generation due to extra-large curvature of surface of the third lens L**3** can be avoided. Preferably, the following condition shall be satisfied, $1.94 \le (R5+R6)/(R5-R6) \le 3.41$.

The thickness on-axis of the third lens L**3** is defined as d5. The following condition: $0.11 \le d5 \le 0.37$ should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.18 \le d5 \le 0.30$ shall be satisfied.

In this embodiment, the fourth lens L**4** has a positive refractive power with a convex object side surface and a convex image side surface relative to the proximal axis.

The focal length of the whole camera optical lens **10** is f, the focal length of the fourth lens L**4** is f4. The following condition should be satisfied: $1.12 \le f4/f \le 3.54$, When the condition is satisfied, the appropriate distribution of refractive power makes it possible that the system has better imaging quality and lower sensitivity. Preferably, the condition $1.79 \le f4/f \le 2.83$ should be satisfied.

The curvature radius of the object side surface of the fourth lens L**4** is defined as R7, the curvature radius of the image side surface of the fourth lens L**4** is defined as R8. The following condition should be satisfied: $0.00 \le (R7+R8)/(R7-R8) \le 0.10$, which fixes the shaping of the fourth lens L**4**. When beyond this range, with the development into the direction of ultra-thin and wide-angle lenses, problem like aberration of the off-axis picture angle is difficult to be corrected. Preferably, the following condition shall be satisfied, $0.0 \le (R7+R8)/(R7-R8) \le 0.08$.

The thickness on-axis of the fourth lens L**4** is defined as d7. The following condition: $0.17 \le d7 \le 0.61$ should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.28 \le d7 \le 0.49$ shall be satisfied.

In this embodiment, the fifth lens L**5** has a negative refractive power with a concave object side surface and a convex image side surface relative to the proximal axis.

The focal length of the whole camera optical lens **10** is f, the focal length of the fifth lens L**5** is f5. The following condition should be satisfied: $-8.02 \le f5/f \le -1.66$, which can effectively smooth the light angles of the camera and reduce the tolerance sensitivity. Preferably, the condition $-5.01 \le f5/f \le -2.08$ should be satisfied.

The curvature radius of the object side surface of the fifth lens L**5** is defined as R9, the curvature radius of the image side surface of the fifth lens L**5** is defined as R10. The following condition should be satisfied: $-5.55 \le (R9+R10)/(R9-R10) \le -1.40$, by which, the shape of the fifth lens L**5** is fixed, when beyond this range, with the development into the direction of ultra-thin and wide-angle lenses, problem like aberration of the off-axis picture angle is difficult to be corrected. Preferably, the following condition shall be satisfied, $-3.47 \le (R9+R10)/(R9-R10) \le -1.75$.

The thickness on-axis of the fifth lens L**5** is defined as d9. The following condition: $0.11 \le d9 \le 0.66$ should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition $0.17 \le d9 \le 0.53$ shall be satisfied.

In this embodiment, the sixth lens L**6** has a positive refractive power with a convex object side surface and a concave image side surface relative to the proximal axis.

The focal length of the whole camera optical lens **10** is f, the focal length of the sixth lens L**6** is f6. The following condition should be satisfied: 1.58≤f6/f≤7.33, which can effectively reduce the sensitivity of lens group used in camera and further enhance the imaging quality. Preferably, the condition 3.33≤f6/f≤8.66 should be satisfied.

The curvature radius of the object side surface of the sixth lens L**6** is defined as R11, the curvature radius of the image side surface of the sixth lens L**6** is defined as R12. The following condition should be satisfied: 8.29≤(R1+R12)(R11−R12)≤33.73, by which, the shape of the sixth lens L**6** is fixed, when beyond this range, with the development into the direction of ultra-thin and wide-angle lenses, problem like aberration of the off-axis picture angle is difficult to be corrected. Preferably, the following condition shall be satisfied, 13.26≤(R11+R12)/(R11−R12)≤26.99.

The thickness on-axis of the sixth lens L**6** is defined as d11. The following condition: 0.34≤d11≤0.12 should be satisfied. When the condition is satisfied, it is beneficial for realization of the ultra-thin lens. Preferably, the condition 0.54≤d11≤0.90 shall be satisfied.

The focal length of the whole camera optical lens **10** is f, the combined focal length of the first lens L and the second lens L**2** is f12. The following condition should be satisfied: 0.46≤f12/f≤1.95, which can effectively avoid the aberration and field curvature of the camera optical lens and can suppress the rear focal length for realizing the ultra-thin lens. Preferably, the condition 0.74≤f12/f≤1.56 should be satisfied.

In this embodiment, the total optical length TTL of the camera optical lens **10** is less than or equal to 5.74 nm, it is beneficial for the realization of ultra-thin lenses. Preferably, the total optical length TTL of the camera optical lens **10** is less than or equal to 5.48 mm.

In this embodiment, the aperture F number of the camera optical lens **10** is less than or equal to 1.96. A large aperture has better imaging performance. Preferably, the aperture F number of the camera optical lens **10** is less than or equal to 1.92.

With such design, the total optical length TTL of the whole camera optical lens **10** can be made as short as possible, thus the miniaturization characteristics can be maintained.

In the following, an example will be used to describe the camera optical lens **10** of the present invention. The symbols recorded in each example are as follows. The unit of distance, radius and center thickness is mm.

TTL: Optical length (the distance on-axis from the object side surface of the first lens L**1** to the image surface).

Preferably, inflexion points and/or arrest points can also be arranged on the object side surface and/or image side surface of the lens, so as that the demand for high quality imaging can be satisfied, the description below can be referred for specific implementable scheme.

The design information of the camera optical lens **10** in the first embodiment of the present invention is shown in the following, the unit of the focal length, distance, radius and center thickness is mm.

The design information of the camera optical lens **10** in the first embodiment of the present invention is shown in the tables 1 and 2.

TABLE 1

	R		d		nd		vd
S1	∞	d0=	−0.278				
R1	1.992	d1=	0.382	nd1	1.6511	v1	38.00
R2	3.288	d2=	0.061				
R3	5.072	d3=	0.659	nd2	1.7086	v2	55.90
R4	45.142	d4=	0.031				
R5	6.290	d5=	0.238	nd3	1.6699	v3	23.50
R6	2.622	d6=	0.227				
R7	9.917	d7=	0.408	nd4	1.5219	v4	55.80
R8	−9.758	d8=	0.393				
R9	−4.041	d9=	0.442	nd5	1.6474	v5	21.40
R10	−8.596	d10=	0.334				
R11	1.124	d11=	0.676	nd6	1.5245	v6	55.70
R12	0.996	d12=	0.583				
R13	∞	d13=	0.210	ndg	1.5168	vg	64.17
R14	∞	d14=	0.578				

Where:

In which, the meaning of the various symbols is as follows.

S**1**: Aperture;

R: The curvature radius of the optical surface, the central curvature radius in case of lens;

R1: The curvature radius of the object side surface of the first lens L**1**;

R2: The curvature radius of the image side surface of the first lens L**1**;

R3: The curvature radius of the object side surface of the second lens L**2**;

R4: The curvature radius of the image side surface of the second lens L**2**;

R5: The curvature radius of the object side surface of the third lens L**3**;

R6: The curvature radius of the image side surface of the third lens L**3**;

R7: The curvature radius of the object side surface of the fourth lens L**4**;

R8: The curvature radius of the image side surface of the fourth lens zs L**4**;

R9: The curvature radius of the object side surface of the fifth lens L**5**;

R10: The curvature radius of the image side surface of the fifth lens L**5**;

R11: The curvature radius of the object side surface of the sixth lens L**6**;

R12: The curvature radius of the image side surface of the sixth lens L**6**;

R13: The curvature radius of the object side surface of the optical filter GF;

R14: The curvature radius of the image side surface of the optical filter GF;

d: The thickness on-axis of the lens and the distance on-axis between the lens;

d0: The distance on-axis from aperture S**1** to the object side surface of the first lens L**1**;

d1: The thickness on-axis of the first lens L**1**;

d2: The distance on-axis from the image side surface of the first lens L**1** to the object side surface of the second lens L**2**;

d3: The thickness on-axis of the second lens L**2**;

d4: The distance on-axis from the image side surface of the second lens L**2** to the object side surface of the third lens L**3**;

d5: The thickness on-axis of the third lens L**3**;

d6: The distance on-axis from the image side surface of the third lens L**3** to the object side surface of the fourth lens L**4**;

d7: The thickness on-axis of the fourth lens L**4**;

d8: The distance on-axis from the image side surface of the fourth lens L**4** to the object side surface of the fifth lens L**5**;

d9: The thickness on-axis of the fifth lens L**5**;

d10: The distance on-axis from the image side surface of the fifth lens L**5** to the object side surface of the sixth lens L**6**;

d11: The thickness on-axis of the sixth lens L**6**;

d12: The distance on-axis from the image side surface of the sixth lens L**6** to the object side surface of the optical filter GF;

d13: The thickness on-axis of the optical filter GF;

d14: The distance on-axis from the image side surface to the image surface of the optical filter GF;

nd: The refractive power of the d line;

nd1: The refractive power of the d line of the first lens L**1**;

nd2: The refractive power of the d line of the second lens L**2**;

nd3: The refractive power of the d line of the third lens L**3**;

nd4: The refractive power of the d line of the fourth lens L**4**;

nd5: The refractive power of the d line of the fifth lens L**5**;

nd6: The refractive power of the d line of the sixth lens L**6**;

ndg: The refractive power of the d line of the optical filter GF;

vd: The abbe number;

v1: The abbe number of the first lens L**1**;

v2: The abbe number of the second lens L**2**;

v3: The abbe number of the third lens L**3**;

v4: The abbe number of the fourth lens L**4**;

v5: The abbe number of the fifth lens L**5**;

v6: The abbe number of the sixth lens L**6**;

vg: The abbe number of the optical filter GF.

Table 2 shows the aspherical surface data of the camera optical lens **10** in the embodiment 1 of the present invention.

embodiment 1 of the present invention. In which, P1R1 and P1R2 represent respectively the object side surface and image side surface of the first lens L**1**, P2R1 and P2R2 represent respectively the object side surface and image side surface of the second lens L**2**, P3R1 and P3R2 represent respectively the object side surface and image side surface of the third lens L**3**, P4R1 and P4R2 represent respectively the object side surface and image side surface of the fourth lens L**4**, P5R1 and P5R2 represent respectively the object side surface and image side surface of the fifth lens L**5**, P6R1 and P6R2 represent respectively the object side surface and image side surface of the sixth lens L**6**. The data in the column named "inflexion point position" are the vertical distances from the inflexion points arranged on each lens surface to the optic axis of the camera optical lens **10**. The data in the column named "arrest point position" are the vertical distances from the arrest points arranged on each lens surface to the optic axis of the camera optical lens **10**.

TABLE 3

	Inflexion point number	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	1	1.085		
P1R2	1	1.035		
P2R1	1	1.045		
P2R2	1	0.335		
P3R1	3	0.345	1.015	1.235
P3R2	0			
P4R1	1	0.995		
P4R2	2	0.895	1.365	
P5R1	1	1.365		
P5R2	0			
P6R1	3	0.485	1.875	2.235
P6R2	1	0.605		

TABLE 2

	Conic Index	Aspherical Surface Index						
	k	A4	A6	A8	A10	A12	A14	A16
R1	−2.0487E−01	−0.012699579	0.004490503	−0.013420136	0.014132451	−0.009848587	0.003749456	−1.18E−03
R2	3.2231E+00	−0.025317599	−0.04599961	0.041794925	0.005534923	−0.013680201	0.003180828	−0.001664806
R3	−2.2947E+00	0.013549238	−0.037500252	0.007753872	0.044344906	−0.023352281	−0.001247479	−0.000300186
R4	1.2377E+03	−0.014458108	0.009874294	−0.12871615	0.074560721	0.014941845	−0.014564226	0.000314232
R5	9.5470E+00	−0.12031665	0.003368659	−0.036451854	−0.031611557	0.086958597	−0.031155906	0.000148439
R6	−1.4071E+01	−0.011981133	0.036659744	−0.12741003	0.19526705	−0.13051287	0.032506586	0.000968243
R7	−6.8579E+00	−0.028635757	−0.014751433	0.073048534	−0.055654106	−0.000454053	2.60E−02	−1.30E−02
R8	2.5428E+01	−0.021844476	−0.064267304	0.13062447	−0.097046987	0.041572652	−7.31E−03	−1.20E−04
R9	−5.5502E+01	0.11051273	−0.29096806	0.39525808	−0.43805505	3.05E−01	−1.16E−01	1.81E−02
R10	−1.3213E+02	−0.10211335	0.20686057	−0.26252897	1.75E−01	−6.52E−02	1.27E−02	−9.87E−04
R11	−6.3227E+00	−0.10211335	0.029131537	−0.003475991	4.20321E−05	4.70367E−05	2.78E−06	−1.04E−06
R12	−4.7982E+00	−0.13192204	0.016838296	−0.002659274	1.88E−04	2.71E−06	−7.77E−07	1.12E−09

Among them, K is a conic index, A4, A6, A8, A10, A12, A14, A16 are aspheric surface indexes.

IH: Image height

$$y=(x^2/R)/[1+\{1-(k+1)(x^2/R^2)\}^{1/2}]+A4x^4\pm A6x^6+A8x^8\pm A10x^{10}+A12x^{12}+A14x^{14}+A16x^{16} \quad (1)$$

For convenience, the aspheric surface of each lens surface uses the aspheric surfaces shown in the above condition (1). However, the present invention is not limited to the aspherical polynomials form shown in the condition (1).

Table 3 and table 4 show the inflexion points and the arrest point design data of the camera optical lens **10** lens in

TABLE 4

	Arrest point number	Arrest point position 1
P1R1	0	
P1R2	0	
P2R1	0	
P2R2	1	0.505
P3R1	1	0.575
P3R2	0	
P4R1	1	1.105
P4R2	1	1.165

TABLE 4-continued

	Arrest point number	Arrest point position 1
P5R1	0	
P5R2	0	
P6R1	1	1.015
P6R2	1	1.385

FIG. **2** and FIG. **3** show the longitudinal aberration and lateral color schematic diagrams after light with a wavelength of 486.1 nm, 587.6 nm and 656.3 nm passes the camera optical lens **10** in the first embodiment. FIG. **4** shows the field curvature and distortion schematic diagrams after light with a wavelength of 587.6 nm passes the camera optical lens **10** in the first embodiment, the field curvature S

TABLE 5-continued

	R	d		nd		vd	
R10	−13.270	d10=	0.316				
R11	1.113	d11=	0.747	nd6	1.5836	v6	55.70
R12	1.018673	d12=	0.509				
R13	∞	d13=	0.210	ndg	1.5168	vg	64.17
R14	∞	d14=	0.504				

Table 6 shows the aspherical surface data of each lens of the camera optical lens **20** in embodiment 2 of the present invention.

TABLE 6

	Conic Index	Aspherical Surface Index						
	k	A4	A6	A8	A10	A12	A14	A16
R1	−3.6607E−01	−0.01641141	0.002178792	−0.015681725	0.012225342	−0.013008713	0.000407559	−9.36E−03
R2	3.0160E+00	−0.032056685	−0.045987444	0.042208986	0.005541153	−0.013964405	0.002806521	−0.00203768
R3	−2.0053E+00	0.012698692	−0.040166	0.006330056	0.04321446	−0.023746361	−0.001406275	−0.000373081
R4	−1.0605E+06	−0.019402968	0.009556962	−0.12870636	0.074334119	0.014740111	−0.01465139	2.73E−04
R5	1.1494E+01	−0.11771033	0.003257652	−0.03648589	−0.031453713	0.087109878	−0.031072511	0.000188969
R6	−1.8089E+01	−0.018391385	0.035746846	−0.13056392	0.19299578	−0.13166809	0.031944133	0.000813639
R7	5.5159E+00	−0.024994228	−0.023647202	0.067423312	−0.057813553	−0.001234992	0.02625252	−1.27E−02
R8	2.5228E+01	−0.024990469	−0.060817667	0.13030761	−0.097022559	0.04161861	−0.007274164	−9.37E−05
R9	−4.7662E+01	0.11474186	−0.28905345	0.39554008	−0.438131	0.30502683	−1.16E−01	0.018068279
R10	−1.3584E+04	−0.09979409	0.20574323	−0.26242577	0.17476847	−0.06514848	0.012660321	−9.89E−04
R11	−3.2897E+00	−0.09979409	0.028902067	−0.00354041	3.03983E−05	4.59769E−05	2.85836E−06	−9.59E−07
R12	−3.5873E+00	−0.1327499	0.016691767	−0.002719838	1.86E−04	3.29E−06	−8.03E−07	6.12E−09

in FIG. **4** is a field curvature in the sagittal direction, T is a field curvature in the meridian direction.

Table 13 shows the various values of the embodiments 1, 2, 3, and the values corresponding with the parameters which are already specified in the conditions.

As shown in Table 13, the first embodiment satisfies the various conditions.

In this embodiment, the pupil entering diameter of the camera optical lens is 2.212 mm, the full vision field image height is 3.512 mm, the vision field angle in the diagonal direction is 79.78°, it has wide-angle and is ultra-thin, its on-axis and off-axis chromatic aberrations are fully corrected, and it has excellent optical characteristics.

Embodiment 2

Embodiment 2 is basically the same as embodiment 1, the meaning of its symbols is the same as that of embodiment 1, in the following, only the differences are described.

Table 5 and table 6 show the design data of the camera optical lens **20** in embodiment 2 of the present invention.

TABLE 5

	R	d		nd		vd	
S1	∞	d0=	−0.121				
R1	2.517	d1=	0.300	nd1	1.3463	v1	38.00
R2	3.154	d2=	0.046				
R3	3.723	d3=	0.701	nd2	1.7816	v2	55.90
R4	77.584	d4=	0.043				
R5	5.668	d5=	0.247	nd3	1.5958	v3	23.50
R6	2.717	d6=	0.213				
R7	8.738	d7=	0.365	nd4	1.5668	v4	55.80
R8	−8.383	d8=	0.381				
R9	−4.789	d9=	0.213	nd5	1.5540	v5	21.40

Table 7 and table 8 s bow the inflexion points and the arrest point design data of the camera optical lens **20** lens in embodiment 2 of the present invention.

TABLE 7

	Inflexion point number	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	1	0.805		
P1R2	1	0.995		
P2R1	1	0.995		
P2R2	1	0.115		
P3R1	3	0.365	0.995	1.255
P3R2	2	0.705	1.155	
P4R1	1	0.675		
P4R2	1	0.905		
P5R1	1	1.375		
P5R2	0			
P6R1	3	0.585	1.975	2.225
P6R2	1	0.675		

TABLE 8

	Arrest point number	Arrest point position 1	Arrest point position 2
P1R1	0		
P1R2	0		
P2R1	0		
P2R2	1	0.225	
P3R1	2	0.615	1.175
P3R2	0		
P4R1	1	0.985	
P4R2	1	1.175	
P5R1	0		
P5R2	0		
P6R1	1	1.175	
P6R2	1	1.545	

FIG. **6** and FIG. **7** show the longitudinal aberration and lateral color schematic diagrams after light with a wavelength of 486.1 nm, 587.6 nm and 656.3 nm passes the camera optical lens **20** in the second embodiment. FIG. **8** shows the field curvature and distortion schematic diagrams after light with a wavelength of 587.6 nm passes the camera optical lens **20** in the second embodiment.

As shown in Table 13, the second embodiment satisfies the various conditions.

In this embodiment, the pupil entering diameter of the camera optical lens is 1.791 mm, the full vision field image height is 3.512 mm, the vision field angle in the diagonal direction is 91.79°, it has wide-angle and is ultra-thin, its on-axis and off-axis chromatic aberrations are fully corrected, and it has excellent optical characteristics.

Embodiment 3

Embodiment 3 is basically the same as embodiment 1, the meaning of its symbols is the same as that of embodiment 1, in the following, only the differences are described.

Table 9 and table 10 show the design data of the camera optical lens **30** in embodiment 3 of the present invention.

TABLE 9

	R	d		nd		vd	
S1	∞	d0=	−0.189				
R1	2.141	d1=	0.232	nd1	1.6997	v1	38.00
R2	3.066	d2=	0.098				
R3	5.436	d3=	0.857	nd2	2.0996	v2	55.90
R4	44.795	d4=	0.040				
R5	6.392	d5=	0.226	nd3	1.7293	v3	23.50
R6	2.865	d6=	0.193				
R7	10.842	d7=	0.348	nd4	1.5699	v4	55.80
R8	−9.427	d8=	0.385				
R9	−4.455	d9=	0.295	nd5	1.7460	v5	21.40
R10	−12.561	d10=	0.337				
R11	1.141	d11=	0.690	nd6	1.5330	v6	55.70
R12	1.01893	d12=	0.494				
R13	∞	d13=	0.210	ndg	1.5168	vg	64.17
R14	∞	d14=	0.490				

Table 10 shows the aspherical surface data of each lens of the camera optical lens **30** in embodiment 3 of the present invention.

TABLE 10

	Conic Index	Aspherical Surface Index						
	k	A4	A6	A8	A10	A12	A14	A16
R1	−3.1299E−01	−0.016786607	0.009308066	−0.018151555	0.008857093	−0.012869596	0.003260505	1.34E−04
R2	2.9869E+00	−0.026897984	−0.050468875	0.043377377	0.006662644	−0.013920017	0.002217506	−0.002880286
R3	−7.6410E−01	0.014826554	−0.035795775	0.006282858	0.043337538	−0.023544868	−0.001064065	−2.1248E−05
R4	1.2469E+03	−0.014360986	0.009859669	−0.12846802	0.074672054	0.015006086	−0.014512337	0.000353144
R5	1.0599E+01	−0.11910475	0.004392826	−0.036460108	−0.031639894	0.086902322	−0.031235771	6.96949E−05
R6	−1.3287E+01	−0.011369791	0.041835507	−0.12081716	0.19642329	−0.13089129	0.032067961	0.000703119
R7	3.9792E+01	−0.026971492	−0.013443911	0.070607345	−0.0556176	0.000708666	0.026777429	−0.012728117
R8	1.3211E+01	−0.018211663	−0.062273533	0.13135616	−0.096933648	0.041613539	−0.007243027	−5.91E−05
R9	−4.8319E+01	0.10610021	−0.29832916	0.39580439	−0.43751873	0.30510089	−1.16E−01	1.78E−02
R10	−8.3905E+01	−0.10728536	0.20484792	−0.26279674	0.17459845	−0.065182465	0.012646462	−1.00E−03
R11	−6.1688E+00	−0.10728536	0.029222643	−0.003489008	3.29482E−05	4.66605E−05	2.81722E−06	−1.00E−06
R12	−4.0194E+00	−0.13020282	0.016538963	−0.002709631	1.87E−04	2.63E−06	−7.52E−07	7.25E−09

Table 11 and table 12 show the inflexion points and the arrest point design data of the camera optical lens **30** lens in embodiment 3 of the present invention.

TABLE 11

	Inflexion point number	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	1	0.895		
P1R2	1	0.975		
P2R1	1	1.045		
P2R2	1	0.345		
P3R1	2	0.345	1.015	
P3R2	0			
P4R1	1	1.065		
P4R2	1	0.845		
P5R1	0			
P5R2	0			
P6R1	3	0.495	1.885	2.235
P6R2	1	0.665		

TABLE 12

	Arrest point number	Arrest point position 1
P1R1	0	
P1R2	0	
P2R1	0	
P2R2	1	0.505
P3R1	1	0.575
P3R2	0	
P4R1	1	1.165
P4R2	1	1.095
P5R1	0	
P5R2	0	
P6R1	1	1.025
P6R2	1	1.545

FIG. **10** and FIG. **11** show the longitudinal aberration and lateral color schematic diagrams after light with a wavelength of 486.1 nm, 587.6 nm and 656.3 nm passes the camera optical lens **30** in the third embodiment. FIG. **12** shows the field curvature and distortion schematic diagrams after light with a wavelength of 587.6 nm passes the camera optical lens **30** in the third embodiment.

As shown in Table 13, the third embodiment satisfies the various conditions.

In this embodiment, the pupil entering diameter of the camera optical lens is 1.985 mm, the full vision field image height is 3.512 mm, the vision field angle in the diagonal direction is 85.92°, it has wide-angle and is ultra-thin, its on-axis and off-axis chromatic aberrations are fully corrected, and it has excellent optical characteristics.

TABLE 13

	Embodiment 1	Embodiment 2	Embodiment 3
f	4.202	3.404	3.772
f1	6.953	32.085	9.194
f2	8.009	4.983	5.563
f3	−6.893	−9.044	−7.318
f4	9.492	7.607	8.903
f5	−12.247	−13.650	−9.400
f6	20.431	10.776	18.436
f12	3.861	4.434	3.576
(R1 + R2)/(R1 − R2)	−4.073	−8.899	−5.630
(R3 + R4)/(R3 − R4)	−1.253	−1.101	−1.276
(R5 + R6)/(R5 − R6)	2.430	2.842	2.625
(R7 + R8)/(R7 − R8)	0.008	0.021	0.070
(R9 + R10)/(R9 − R10)	−2.774	−2.129	−2.099
(R11 + R12)/(R11 − R12)	16.574	22.490	17.760
f1/f	1.655	9.426	2.438
f2/f	1.906	1.464	1.475
f3/f	−1.640	−2.657	−1.940
f4/f	2.259	2.235	2.361
f5/f	−2.914	−4.010	−2.492
f6/f	4.862	3.166	4.888
f12/f	0.919	1.303	0.948
d1	0.382	0.300	0.232
d3	0.659	0.701	0.857
d5	0.238	0.247	0.226
d7	0.408	0.365	0.348
d9	0.442	0.213	0.295
d11	0.676	0.747	0.690
Fno	1.900	1.900	1.900
TTL	5.222	4.796	4.893
d1/TTL	0.073	0.063	0.047
d3/TTL	0.126	0.146	0.175
d5/TTL	0.046	0.051	0.046
d7/TTL	0.078	0.076	0.071
d9/TTL	0.085	0.044	0.060
d11/TTL	0.129	0.156	0.141
n1	1.6511	1.3463	1.6997
n2	1.7086	1.7816	2.0996
n3	1.6699	1.5958	1.7293
n4	1.5219	1.5668	1.5699
n5	1.6474	1.5540	1.7460
n6	1.5245	1.5836	1.5330
v1	38.0000	38.0000	38.0000
v2	55.9000	55.9000	55.9000
v3	23.5000	23.5000	23.5000
v4	55.8000	55.8000	55.8000
v5	21.4000	21.4000	21.4000
v6	55.7000	55.7000	55.7000

It is to be understood, however, that even though numerous characteristics and advantages of the present exemplary embodiments have been set forth in the foregoing description, together with details of the structures and functions of the embodiments, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms where the appended claims are expressed.

What is claimed is:

1. A camera optical lens comprising, from an object side to an image side in sequence: a first lens, a second lens having a positive refractive power, a third lens having a negative refractive power, a fourth lens, a fifth lens, and a sixth lens; wherein the camera optical lens further satisfies the following conditions:

$0.1 \leq f1/f \leq 10$;

$1.7 \leq n2 \leq 2.2$;

$0.01 \leq d3/TTL \leq 0.2$;

$1.12 \leq f4/f \leq 3.54$;

where

f: the focal length of the camera optical lens;

f1: the focal length of the first lens;

f4: the focal length of the fourth lens;

n2: the refractive power of the second lens;

d3: the thickness on-axis of the second lens;

TTL: the total optical length of the camera optical lens.

2. The camera optical lens as described in claim **1**, wherein the first lens is made of plastic material, the second lens is made of glass material, the third lens is made of plastic material, the fourth lens is made of plastic material, the fifth lens is made of plastic material, the sixth lens is made of plastic material.

3. The camera optical lens as described in claim **1** further satisfying the following conditions:

$0.88 \leq f1/f \leq 9.71$;

$1.7 \leq n2 \leq 2.1$;

$0.07 \leq d3/TTL \leq 0.19$.

4. The camera optical lens as described in claim **1**, wherein first lens has a positive refractive power with a convex object side surface and a concave image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$-17.80 \leq (R1+R2)/(R1-R2) \leq -2.72$;

$0.12\ mm \leq d1 \leq 0.57\ mm$; where

R1: the curvature radius of object side surface of the first lens;

R2: the curvature radius of image side surface of the first lens;

d1: the thickness on-axis of the first lens.

5. The camera optical lens as described in claim **4** further satisfying the following conditions:

$-11.12 \leq (R1+R2)/(R1-R2) \leq -3.39$;

$0.19\ mm \leq d1 \leq 0.46\ mm$.

6. The camera optical lens as described in claim **1**, wherein the second lens has a convex object side surface and a concave image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$0.73 \leq f2/f \leq 2.86$;

$-2.55 \leq (R3+R4)/(R3-R4) \leq -0.73$;

$0.33\ mm \leq d3 \leq 1.29\ mm$; where:

f: the focal length of the camera optical lens;

f2: the focal length of the second lens;

R3: the curvature radius of the object side surface of the second lens;

R4: the curvature radius of the image side surface of the second lens; and

d3: the thickness on-axis of the second lens.

7. The camera optical lens as described in claim **6** further satisfying the following conditions:

$1.17 \leq f2/f \leq 2.29$;

$-1.60 \leq (R3+R4)/(R3-R4) \leq -0.92$;

$0.53\ mm \leq d3 \leq 1.03\ mm$.

8. The camera optical lens as described in claim **1**, wherein the third lens has a convex object side surface and a concave image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$-5.31 \leq f3/f \leq -1.09$;

$1.22 \leq (R5+R6)/(R5-R6) \leq 4.26$;

$0.11\ mm \leq d5 \leq 0.37\ mm$; where

f: the focal length of the camera optical lens;

f3: the focal length of the third lens;

R5: the curvature radius of the object side surface of the third lens;

R6: the curvature radius of the image side surface of the third lens; and

d5: the thickness on-axis of the third lens.

9. The camera optical lens as described in claim **8** further satisfying the following conditions:

$-3.32 \le f3/f \le -1.37$;

$1.94 \le (R5+R6)/(R5-R6) \le 3.41$;

$0.18\ mm \le d5 \le 0.30\ mm$.

10. The camera optical lens as described in claim **1**, wherein the fourth lens has a positive refractive power with a convex object side surface and a convex image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$0.00 \le (R7+R8)/(R7-R8) \le 0.10$;

$0.17\ mm \le d7 \le 0.61\ mm$; where

R7: the curvature radius of the object side surface of the fourth lens;

R8: the curvature radius of the image side surface of the fourth lens;

d7: the thickness on-axis of the fourth lens.

11. The camera optical lens as described in claim **10** further satisfying the following conditions:

$1.79 \le f4/f \le 2.83$;

$0.01 \le (R7+R8)/(R7-R8) \le 0.08$;

$0.28\ mm \le d7 \le 0.49\ mm$.

12. The camera optical lens as described in claim **1**, wherein the fifth lens has a negative refractive power with a concave object side surface and a convex image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$-8.02 \le f5/f \le -1.66$;

$-5.55 \le (R9+R10)/(R9-R10) \le -1.40$;

$0.11\ mm \le d9 \le 0.66\ mm$; where

f: the focal length of the camera optical lens;

f5: the focal length of the fifth lens;

R9: the curvature radius of the object side surface of the fifth lens;

R10: the curvature radius of the image side surface of the fifth lens; and

d9: the thickness on-axis of the fifth lens.

13. The camera optical lens as described in claim **12** further satisfying the following conditions:

$-5.01 \le f5/f \le -2.08$;

$-3.47 \le (R9+R10)/(R9-R10) \le -1.75$;

$0.17\ mm \le d9 \le 0.53\ mm$.

14. The camera optical lens as described in claim **1**, wherein the sixth lens has a positive refractive power with a convex object side surface and a concave image side surface relative to the proximal axis; the camera optical lens further satisfies the following conditions:

$1.58 \le f6/f \le 7.33$;

$8.29 \le (R11+R12)/(R11-R12) \le 33.73$;

$0.34\ mm \le d11 \le 1.12\ mm$; where

f: the focal length of the camera optical lens;

f6: the focal length of the sixth lens;

R11: the curvature radius of the object side surface of the sixth lens;

R12: the curvature radius of the image side surface of the sixth lens; and

d11: the thickness on-axis of the sixth lens.

15. The camera optical lens as described in claim **14** further satisfying the following conditions:

$2.53 \le f6/f \le 5.87$;

$13.26 \le (R11+R12)/(R11-R12) \le 26.99$;

$0.54\ mm \le d11 \le 0.90\ mm$.

16. The camera optical lens as described in claim **1** further satisfying the following condition:

$0.46 \le f12/f \le 1.95$; where

f12: the combined focal length of the first lens and the second lens;

f: the focal length of the camera optical lens.

17. The camera optical lens as described in claim **16** further satisfying the following condition:

$0.74 \le f12/f \le 1.56$.

18. The camera optical lens as described in claim **1**, wherein the total optical length TTL of the camera optical lens is less than or equal to 5.74 mm.

19. The camera optical lens as described in claim **18**, wherein the total optical length TTL of the camera optical lens is less than or equal to 5.48 mm.

20. The camera optical lens as described in claim **1**, wherein the aperture F number of the camera optical lens is less than or equal to 1.96.

21. The camera optical lens as described in claim **20**, wherein the aperture F number of the camera optical lens is less than or equal to 1.92.

* * * * *